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The narrative truth about scientific misinformation

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Science and storytelling mean different things when they speak of truth. This difference leads some to blame storytelling for presenting a distorted view of science and contributing to misinformation. Yet others celebrate storytelling as a way to engage audiences and share accurate scientific information. This review disentangles the complexities of how storytelling intersects with scientific misinformation. Storytelling is the act of sharing a narrative, and science and narrative represent two distinct ways of constructing reality. Where science searches for broad patterns that capture general truths about the world, narratives search for connections through human experience that assign meaning and value to reality. I explore how these contrasting conceptions of truth manifest across different contexts to either promote or counter scientific misinformation. I also identify gaps in the literature and identify promising future areas of research. Even with their differences, the underlying purpose of both science and narrative seeks to make sense of the world and find our place within it. While narrative can indeed lead to scientific misinformation, narrative can also help science counter misinformation by providing meaning to reality that incorporates accurate science knowledge into human experience.

narrative | science | misinformation | education | persuasion

> Layden was a healthy toddler who loved exploring new things and following his cat Peekaboo around the house. His mother, Sandra, had been warned by some of her friends about the dangers of too many vaccinations, but she trusted her doctor and took Layden to get the recommended vaccines. Shortly afterwards, Layden became more withdrawn, showing little interest in his toys, his family or even Peekaboo. Layden was eventually diagnosed with autism spectrum disorder. Science says that multiple vaccines are safe, but Sandra's experience tells a different story.

The threat of misinformation is not unique to science, but for those who spend their time creating scientific knowledge, it can get personal. As in other contexts, misinformation can lead individuals to make uninformed decisions that negatively impact their lives or society at large. However, the acceptance of misinformation also discounts the role that science plays within society—that of discovering and disseminating accurate information about the world. In this sense, misinformation is also an insult to the very scientific endeavor.

While the causes of misinformation are complex (1), one source often blamed is storytelling. Storytelling may present a "distorted and unrepresentative display of data—one that does not do justice to experimental complexities and their myriad of interpretations" (ref. 2, p. 1045). Storytelling as a genre may not be able to meet the requirements that "scientific writing be cautious, circumspect, and tentative" (ref. 3, p. 560). Storytellers of fictional television and film content "maintain a flexible notion of scientific realism. . .that puts them at odds with scientists who take a more demanding conception of scientific accuracy.

Part of this association may be because storytelling, like misinformation, is also sometimes seen as fundamentally opposed to scientific discovery. "The plural of anecdote is not data" has become a scientific proverb to refute the notion that a single story will generalize to some larger truth. The vaccine story that begins this review exemplifies this contrast. While science searches for broad patterns that capture general truths about the world, storytelling celebrates the particulars of a single experience, regardless of how representative that experience may be. Additionally, in many cases, a particular experience can be more influential upon decision making.

However, the role that storytelling plays within the creation and dissemination of scientific misinformation may not be so clear. There are just as many calls that promote storytelling as a means to benefit science and potentially combat misinformation. Storytelling is claimed to better engage audiences with science (5), make science more meaningful (6), and portray science as more inclusive (7). Storytelling can communicate accurate scientific information both within the classroom (8) and through fictional entertainment (9).

The vaccine story that begins this Introduction also exemplifies the complex relationship between misinformation and storytelling. While it may not be representative of what science has determined is likely to happen and while a reader may likely make the mistake of assigning causation where there is only correlation, nothing in the story is scientifically inaccurate. The story may accurately capture an individual's experience related to vaccines. This represents a very different type of misinformation as compared with that arising from individuals who create, share, or believe information that is scientifically inaccurate. Storytelling is still subject to the same drivers of misinformation that impact other types of information, such as motivated reasoning, echo chambers, and recency effects (1) and can also disseminate information that is scientifically untrue. Yet, storytelling also introduces unique considerations that require us to expand our conceptualizations of scientific misinformation.

The purpose of this review is to disentangle the distinctive complexities of how storytelling intersects with scientific misinformation. I have examined communication and science education literature published between 1990 and 2018 that connects storytelling with either science or misinformation and have included additional literature pulled from political science, psychology, anthropology, and sociology when relevant. I primarily focus on the results of experimental methods but include theoretical and argumentative viewpoints when helpful.

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As the following discussion will detail, scientific storytelling can both contribute to scientific misinformation as well as counter many of its effects. Much of the power and pitfall of scientific storytelling arises from the difference in how science and stories evaluate truth.

What's the Story?

> As if there could possibly be true stories; things happen one way and we tell about them in the opposite sense. (ref. 10, p. 39)

Storytelling is the act of sharing information through a narrative. Narrative is the key construct within this literature and represents a message that describes the experience of specific characters across a series of related events over a defined time period—a triumvirate of character, causality, and temporality (11). At its core, narrative is the telling of someone's experience about something.

Within the field of narratology, the concepts of narrative and story are distinct (12). A story represents the actual collection of events and their relations to each other. It is the "what happened." Narrative is the subjective telling of that story. It is the "how to tell what happened." What events should be included in the narrative? Through which character's perspective should the narrative be told? Should the events be shared in chronological order, or would some foreshadowing make for a more effective story? These countless choices allow for an unlimited number of narratives to be crafted around a single story. While this differentiation between story and narrative is important because it emphasizes there must always be a narrator making subjective choices in creating a narrative, most of the literature examined use the two terms interchangeably to conceptualize a message structured using a narrative format, and I will use the term narrative for this purpose moving forward.

The core definition of narrative may be well bounded, but the manifestation of narrative within science contexts is strikingly diverse. Narratives can communicate about science through text, audio, video, and interactive modalities. They are present in textbooks, television, news, film, advertisements, and social media posts. The subjective choices inherent in the creation of science narratives can lead to significant differences in length, perspective, and quality of craftmanship. The goals underlying science narratives are similarly varied. They can be created to teach science in the classroom or persuade decision makers to support a particular policy. They may be part of a broad communication campaign to change public attitudes and behaviors or merely exemplify a larger theme within a single news story. Or they may simply be personal experiences about science shared among friends.

In this review, I limit my examination to literature that conceptualizes this diversity of narrative through the lens of an external message that aims to accomplish some communicative aim. This excludes a number of other conceptualizations of narrative that, while important, are beyond the scope of this review. I therefore am not considering narratives as individual schemas, general frames of thought, or shared cultural viewpoints. I do not automatically conceptualize news stories as narratives, although literature that examines narrative structures within news is included. Also, I do not include associations between narrative and indigenous knowledge as is sometimes contrasted with scientific knowledge (13).

Science vs. Narrative?

> Physics must eventuate in predicting something that it testably right, however much it may speculate. Stories have no such need for testability. (ref. 14, p. 14)

Are science and narrative truly at odds? Additionally, is this contrast a cause of scientific misinformation?

Research into vaccine communication is often grounded in this assumption, viewing narrative as a frequent source of inaccurate information that influences vaccine attitudes and behaviors away from science. While the causes underlying vaccine hesitancy are complex (15), the influence of narratives is notably salient as antivaccine advocates frequently rely on personal testimonies to argue that vaccines are neither safe nor effective (16). Research finds that these adverse narratives have a disproportionate impact on vaccine attitudes and behaviors even when paired with accurate scientific risk information (17, 18), and this biasing effect of narrative information is stubbornly difficult to counter (19). Research more broadly using any exemplification theory framework will also likely conceptualize a similar dichotomy between narrative and science, where studies often compare statistical risk information against exemplars to see which has a greater influence on attitudes and behaviors. The strength of the narrative bias remains strong across a number of contexts (20, 21).

At a cognitive level, these differences arise because science and narrative represent two distinct ways of constructing reality. In his seminal work, Bruner describes how scientific thinking, or what he calls the paradigmatic mode of thought, serves a different purpose than the narrative mode of thought. The goal of scientific thinking is to "transcend the particular" to provide conclusions and uncover general truths about the world that are empirically true (ref. 14, p. 13). The goal of narrative thinking is to explore human perspectives that confer meaning to reality. Where scientific thinking seeks truth, narrative thinking seeks connections and interpretations through human experience (14). This fundamental difference alters how the products of each mode are evaluated. Scientific findings are judged on their alignment with external truth. Narratives are judged on the lifelikeness of their human interactions. This explains why even fictional narratives, while untrue relative to the external world, can nevertheless offer a realistic exploration of human experience and still be considered truthful (14). This dichotomy of purpose reveals itself when science and narrative appear in conflict. For example, Kirby (4) explores how scientists and television producers approached incorporating science into entertainment programming. Scientists were more focused on the accuracy of the science with regard to the external world (scientific thinking), while the producers were focused more on the authenticity and plausibility of how the science interacted within the story (narrative thinking) (4).

The messages that are created to communicate science are therefore manifestations of the mode of thinking that they were designed to satisfy. In the previous section I defined narrative formats, and we can now see that their defining features of character, causality, and temporality satisfy well the narrative thinking needs for lifelikeness, connections, and human interactions. In contrast, there are different and more common formats for scientific information. Expository formats explain what is known about a topic and are the most common formats in scientific textbooks. Argumentative formats create a logical chain of claims and evidence to justify why a statement is known or should be accepted (22). Both of these formats satisfy well the scientific thinking needs for generalization and empirical verification.

It is important to note that in practice, this distinction between science and narrative can blur. Some qualitative methodologies involve the rigorous collection and construction of narratives to capture specific examples of a phenomenon under study, such as with case studies or ethnographies. In cases such as these, the connections and human interactions afforded by narrative are used in service of a scientific goal that will be evaluated on its external realism. At an even broader epistemological level, some scholars within the philosophy of science argue that scientific facts are not the result of uncovering independent truth but

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instead, are constructed objects resulting from the intersection of many social factors, including narratives (23). This literature that argues narratives challenge the very ideologies of science is important to note but extends beyond the scope of this review.

Acknowledging these complex intersections, narrative remains meaningfully distinct from science based on contrasting evaluations of truth. However, does this difference necessarily lead to scientific misinformation? While narrative may be distinct from science, that does not necessarily mean it is deficient. Narratives may lack the generalizability of science, but they retain more of the surrounding complexity that scientific formats commonly discard, such as the emotional meanings and motivating factors for action (24). Additionally, in science communication contexts where understanding this type of content is desirable, narrative may serve the preferred role.

Therefore, to explore the intersection of narrative and science misinformation, it will be useful to turn from what science and narrative are to what they want to do. By focusing on the goals of science communication, we can see how narratives can both lead audiences toward science misinformation as well as counter misinformation and help science achieve its communication goals. A study surveyed a selection of US university-employed members of the American Association for the Advancement of Science to explore their underlying goals for science communication (25). I will structure the following discussion based on the two most frequent goals cited: 1) informing audiences through knowledge and 2) defending science through persuasion.

The Goal of Scientific Knowledge

The societal role of science is tightly coupled with knowledge. Because science creates and refines what is known about the world, a common goal for science communication is to increase scientific knowledge so people can make informed decisions about their lives. Can narratives assist this goal of increasing scientific knowledge, or do they lead to inaccurate knowledge about science?

If we first conceptualize knowledge as learning scientific facts, research within communication and psychology suggests that the answer to both questions is yes. Narratives can lead to accurate knowledge gains (26), but narratives can just as easily promote the acceptance of inaccurate facts (27). In other words, people are bad at distinguishing specific facts from falsehoods within narratives and often accept information within narratives without scrutiny.

This is a different flavor of misinformation than most of what we have discussed so far. Rather than contrasting outcomes between narrative and scientific information, these studies assume that both accurate and inaccurate information can coexist within narratives. The primary question of interest asks if audiences are able to differentiate between the two and what are the resulting impacts on accurate knowledge. The knowledge claims manipulated are usually simple and concrete facts that are either true or false, and outcomes measure if audiences can either identify the falsehoods or if they afterward accept the falsehoods as true.

Studies consistently find that factual errors are difficult for audiences to identify within narratives and that these errors are usually accepted as fact. Furthermore, this influence is difficult to counter. Prior warning that a narrative will contain false information does not counter the acceptance of misinformation (28). Slowing the presentation of content should permit the allocation of greater mental resources to evaluate truth claims and result in the acceptance of less misinformation. While this has been shown to counter misinformation for nonnarrative messages, it does not for narratives (29). Expertise in a particular area can somewhat decrease the influence of narrative, but not eliminate the effect completely (30), and general background knowledge does not seem to offer any protective effect (31). Even when participants were told that the author of a narrative they just read had intentionally been deceptive, participants derided the author but were still unable to counter the beliefs that had been introduced (32). In fact, information learned through narrative can even lead to an illusion of prior knowledge, where the content becomes so integrated into knowledge structures that the participants believe they knew it all along (26).

There is some variation in influence, such that facts from less realistic narratives (33) and facts without a strong causal connection within the narrative (34) are less readily accepted. Yet, the only successful tactic to counter this type of misinformation has been direct inoculation, where a specific falsehood is noted and corrected before exposure to the narrative (35).

While these results suggest that narratives containing incorrect information can be a stubborn source of misinformation, science knowledge is larger than the acceptance or rejection of concrete facts. The second generation of cognitive science reconceptualizes knowledge away from facts and logical classifications to something more "fuzzy and contextual" with learning occurring through simulation, analogy, and narrative (ref. 36, p.154, 37). The role of science communication in this paradigm is to mediate "between the relatively denotative nature of science text and the expressive nature of everyday thought and language" (ref. 36, p. 170).

One example of a research domain exploring this broader conceptualization of scientific knowledge is science education. Science education examines knowledge acquisition about science across two major settings: 1) formal educational classrooms where science is part of a school curriculum and 2) informal science experiences, such as museums, zoos, after-school programs, citizens science projects, etc., where audiences have more choice in the topic of learning and their level of engagement. A series of reports from the National Academies Press offers evidence-based frameworks for science education across these settings and promotes the use of exploration, reflection, and discussion toward scientific knowledge (38–40). While factual knowledge of science and engineering represents one important measure of science knowledge, also expected are an appreciation of the wonder of science, ability to engage in public discussions on science, critical consumption of scientific and technological information, and the ability to continue to learn about science outside school (39).

Education about the Nature of Science is of particular interest. The Nature of Science represents metacognitive ideas about what science is and how science works, such that science is open to revision in light of new evidence, uses a variety of methods, and is a human endeavor (40). Understanding the Nature of Science is seen as an important bridge linking scientific results, how those results came about, and in what contexts those results can be relevant to society.

Incorporating narrative into science education is seen as one technique to develop these deeper conceptions of scientific knowledge. Narratives are said to generate greater interest and curiosity in science (41); help develop cognitive and critical awareness about science; demonstrate the interconnections between science and society; and offer marginalized groups greater representation and access to science education (42, 43). Narratives have been incorporated into science education contexts in various ways. Door openers represent short anecdotes that do not aim to explain the science but merely illustrate a particular point, raise a question, or engage students (44). Assigning students to create their own narratives can help develop a deeper understanding of wider issues related to the science itself (45). Case studies and historical narratives can serve to humanize science and illustrate connections between science and society (46). These historical narratives, in particular, are often used to teach about the nature of science (47).

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Other scholars have voiced warnings. Narrative may be useful in science education for purposes extrinsic to science, such as increasing interest in science or learning about the context surrounding a discovery, but may not be well suited for topics intrinsic to science that represent the body of scientific knowledge. In these cases, expository and argumentative formats provide the necessary precision, generalizability, and tentativeness for scientific work (3). While generating interest is often beneficial for education, it can also undermine learning if it becomes a distraction (48). Even the act of packaging the history of a scientific discovery into a narrative introduces a misleading mythic structure that can overemphasize the influence of an individual, mask uncertainties, and imply expected results and an underlying moral, which romanticizes the true nature of science (49, 50). Nonetheless, there is significant enthusiasm toward using narrative to enhance knowledge within science education.

Discussion on Knowledge Goals

Does narrative lead to misinformation relative to goals of scientific knowledge? If we conceptualize scientific knowledge as accurate facts, narratives can increase recall, comprehension, and acceptance of scientific information. At the same time, narratives can equally increase recall, comprehension, and acceptance of scientific misinformation because audiences are rarely motivated to distinguish between the two when in narrative form. This agnostic dissemination of scientific truth is less of a concern in education contexts where the narratives are often created, or at least vetted, by instructors and curriculum designers who will ensure that the scientific content within the narratives aligns with the goals of science knowledge. This becomes more of a source of misinformation outside of educational contexts where those creating or sharing narratives need not be concerned about scientific truth.

Why is factual information communicated through narrative so readily accepted and so hard to discredit? The question itself underlines the mismatch between how scientific and narrative processing evaluates truth. Returning to our earlier discussion, the goal of narrative thinking is to build connections between events in order to explore human perspectives. Audiences processing a message with narrative thinking will therefore be focused on making connections between facts and events within the message toward building a truth based on coherence (27, 51). Verifying facts against external knowledge, while an important goal for scientific thinking, can distract from making these internal connections and is only attempted if there are extenuating reasons to do so. In sum, asking why narrative is so poor at upholding truth from falsehood is overlooking its purpose. It is akin to asking why an eagle is so poor at running.

If we instead conceptualize scientific knowledge more broadly, including understanding historical contexts, connections between science and society, or the epistemological Nature of Science, then narrative may have an intrinsic advantage in building and exploring these connections. While current empirical findings may be sparse, there are reasons to be optimistic. A recent report published by the National Academies of Sciences, Engineering, and Medicine describes foundations of learning theory relevant for science education for grades 6 to 12. Many of these themes describe activities for which narrative formats should excel: making connections between new concepts and lived experiences, relating abstractions to concrete examples, creating social and emotional engagement, and developing interest and motivation (40).

The Goal of Scientific Persuasion

A narrative is the product of numerous subjective choices about how to portray characters experiencing a series of events. Because these choices inherently promote one interpretation of the events over other possibilities, narrative is intrinsically persuasive.

Many scientists feel wary about engaging in persuasion (52). The debates surrounding the appropriateness of the 2017 March for Science, where scientists and science supporters around the world marched to combat what they saw as politicization of science, reveal these divisions (53). However, the persuasion conceptualized under this scientific goal is much broader than political advocacy.

Where knowledge goals focus on creating an accurate and representative understanding on some aspect of science, persuasion goals seek to support a particular application or interpretation of that knowledge. Scientific knowledge uncovers truth that explains the world, but it can never dictate what individuals or society should do with that knowledge (54). Assertions that children should follow recommended vaccine schedules; arguments that climate change deserves more attention; even noncontroversial desires to build greater support for science—these are not facts but negotiations of value and therefore fall under the scientific goal of persuasion. Additionally, this goal is often viewed through the lens of defending science from misinformation (25).

How do narratives intersect with misinformation within science persuasion goals? The field of narrative persuasion can offer some guidance. Research in narrative persuasion primarily spans psychology and communication literatures and examines the mechanisms and specific narrative constructions that underlie the persuasive impacts of narratives. Rather than trying to counter narrative bias in exchange for scientific understandings, narrative persuasion embraces narrative bias and explores how to use the characteristics of narrative thinking to build support for specific viewpoints.

Narrative persuasion research is usually experimental where groups of participants read narratives that portray characters experiencing some aspect of a larger phenomenon with a normatively positive or negative conclusion. Outcome measures focus on the degree to which story-consistent attitude or behavior changes occur. Experimental designs can broadly be categorized into contrasts that compare effects between narrative vs. nonnarrative messages, between multiple narrative messages that differ based on their construction, or between external factors that affect how a narrative is interpreted, such as audience demographics or specific reading instructions (55).

Research finds that individuals often change their attitudes and behavioral intentions to align with the perspective portrayed in a narrative. Persuasiveness of a narrative is generally not dependent upon the medium in which it is produced nor its alignment with external truth—fictional narratives can be just as impactful as nonfiction narratives (56, 57).

The Transportation-Imagery Model (58), Extended Elaboration Likelihood Model (59), and Entertainment Overcoming Resistance Model (60) all describe complementary mechanisms where audiences processing narrative messages are so focused on making connections within the story world that they do not have the cognitive resources remaining to generate counterarguments. The audience is therefore more likely to adopt the perspective of the narrative unless they are motivated to actively disengage from the story world and reevaluate the message. Additionally, because audiences often choose narratives for entertainment purposes, they are often unaware that the narrative may be trying to persuade. In this sense, narratives are potentially effective for influencing audiences who might otherwise be more resistant to changing their beliefs or attitudes.

Narrative persuasion is no magic bullet, however. If disengagement occurs—such as through reactance against obvious persuasive intent or perceived contradictions to preexisting values or experience—narratives can lose their unique influence. For instance, a persuasive narrative attempting to sway opinion away from belief in climate change demonstrated the predicted effects of narrative persuasion unless the participant considered that outcome of the message to be harmful, in which case the

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narrative effect was almost completely countered (61). Similarly, a comparison of four different provaccine messages aimed to counter misinformation, including a dramatic narrative about an infant in danger, found that none of the messages led to an increased intent to vaccinate (62). The power of narratives to persuade audiences away from preexisting attitudes therefore depends on creating narratives that maximize narrative thinking about the story world while minimizing elements that may break this engagement and trigger external scrutiny. Success is more likely to occur through audience segmenting (63) and skillful craftsmanship of story features (64).

Whereas the previous literature on science education was centered in a scientific context and incorporated narrative, the literature on narrative persuasion is centered in a narrative framework and occasionally incorporates science as a context. Some of these science-related studies explore how narratives persuade audiences to adopt scientific misinformation (65) or maladaptive behaviors (66). However, more often these studies explore narrative as a way to counter misinformation through persuading audiences in scientifically accurate or recommended directions (67, 68). Yet, the outcomes are not always distinct. Morgan et al. (69) surveyed viewers of six fictional entertainment programs that included organ donation as part of the storyline. Viewers emotionally engaged with the narrative were more likely to adopt the intended positive attitudes toward organ donation, but some viewers also believed there was a black market for organs and that individuals with more money get transplants faster—both of which are inaccurate but were driving the plot of one of the narratives (69).

Health dominates as the primary science-related context with 37% of experimental narrative persuasion articles published between 2000 and 2013 focusing on health persuasion, with no other science topic appearing more than a handful of times (55). A pair of studies synthesized the influence of narrative persuasion just within a health context (70, 71) and suggests that narratives that model the benefits of a healthy behavior or focus on detection or prevention of a health problem are more successful than narratives that show the consequences of an unhealthy behavior or promote its cessation. Likewise, video and audio media were found to be more influential as were text narratives that portrayed characters through a first-person perspective.

Yet, health represents only a very particular slice of science. The foundational motivating value is widely shared and noncontroversial—health is good and should be promoted. Risks and benefits are portrayed at an individual level where the audience could act toward a known solution. Additionally, through an existing doctor–patient relationship, most health contexts can already assume a trusted connection with a scientific expert. Other science contexts do not share these features. Climate change, for instance, does not share a common and noncontroversial foundation of value. The risks and benefits are portrayed at the societal level, and audiences often cannot readily act toward a known solution. Also, climate change is sorely lacking a trusted connection between expert and the public. The broad mechanisms underlying narrative persuasion will likely remain the same regardless of scientific context, but the specific relationships between narrative factors that are most persuasive will likely differ.

A closer look at personification can reveal these potential complexities. Personification is a defining feature of narrative where the experience of a single individual is emphasized to provide an experience of a larger phenomenon. Audiences often use that experience to generalize outward to arrive at a broader understanding of the issue and on which to base their attitudes and behaviors. In the case of vaccines, generalizing outward from a nonrepresentative narrative of harm is the source of frequent misinformation (17). Yet, there are other scientific contexts where a lack of personal experience leaves audiences "too 'coldly rational'" and requires "doses of feeling" for action (ref. 72, p. 320). State legislators exposed to information about the health consequences of low-income communities with limited access to healthy food were more likely to support policies to address the issue when a narrative personalizing the issue accompanied the statistical data than when the narrative was not present (73).

A strength of narrative persuasion literature is its exploration of the many complex mechanisms and relationships that underlie the impact of narratives. However, the particularities of applying narrative persuasion in various scientific contexts remain underexplored. Evidence clearly shows that narratives can effectively persuade audiences toward a particular application or interpretation of scientific knowledge through a number of cognitive and emotional mechanisms. Whether or not this persuasion creates or counters scientific misinformation depends on the goals of the narrator and how the narrative is constructed.

Discussion on Persuasion Goals

How does narrative relate to misinformation within goals of scientific persuasion? The power of narrative lies in its ability to create meaning from the scattered facts of reality and attach normative evaluations toward evaluating that meaning. Whether or not those normative evaluations lead to scientific misinformation or help to counter it depends on the choices made by the narrator creating the narrative.

Narratives are intricate message structures. The previous synthesis of narrative persuasion literature shows the complex interactions taking place between factors like character perspective, emotional reactions, and mental imagery that build enough narrative realism to promote acceptance of the message portrayed. These interactions can create vivid realities that capture the depth with which people connect to the world, resonating with past fears or joys and realizing how new connections between ideas relate to their lived experience.

This is why narrative is valuable for combatting scientific misinformation. We have seen how particularly difficult it can be to counter a narrative of misinformation with facts. However, a narrative of misinformation can be countered with a better narrative. Narrative provides science with a tool to create and disseminate compelling understandings of reality that both are accurate with respect to external truth and promote goals that science wants to promote. The caveat is that science loses its relative advantage with respect to truth when it crosses the threshold into the narrative realm. Having the most externally accurate information does not necessarily result in a better story. In this domain, science has to compete on an equal footing with narrators who are not bound to creating a narrative reality that aligns with scientific knowledge. How scientists manage this narrative competition is essentially an ethical question (74).

The Next Chapter

> Perhaps this is why tyrants so hate and fear poets and novelists and, yes, historians. Even more than they fear scientists, who, though they create possible worlds, leave no place in them for alternative personal perspectives on those worlds. (ref. 14, p. 54)

Science and narrative are distinct in how they evaluate truth. Science seeks to uncover an empirical understanding of the world and is judged on its alignment with external truth. Narrative seeks to explore human perspectives that provide meaning to reality and is judged by the lifelikeness of its internal connections. Left to their own devices, this difference can promote scientific misunderstanding as people build their understanding of reality from collections of narratives that prioritize a good story over accurate content. However, the underlying purposes of both science and narrative are not that different. They both seek to make sense of the world and find our place within it. By bridging the two, narrative can also help science counter

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misinformation by providing meaning to reality that incorporates accurate science knowledge into human experience.

The literature synthesized in this review show that both avenues are possible and are occurring within our information environment. This final section looks forward to distinguish five areas that remain underexplored that may deepen both our understanding of the intersection of narrative and scientific misinformation and our ability to act strategically within it.

Dimensions and Contexts. Existing research provides a wealth of perspectives from which narrative has been examined and its mechanisms explored. However, the incredible range of forms that narratives can take, contexts in which they can have an effect, and outcome measures they may impact has not yet been deconstructed theoretically or contrasted empirically. What types of narrative constructions have the greatest impact on which outcome variables within science education? How do narrative persuasion mechanisms differ in impact across varied scientific contexts? Recent meta-analytic work is moving in this direction (56, 70), but there remains plenty of variation left to explore. This type of research is important for being able to create effective interventions to address scientific misinformation but is also so contextual that additional research will result in small but incremental gains along very specific lines of interest.

Bring Nature of Science out of the Classroom. When science uses narrative to counter narratives of misinformation, it must compete with other storytellers who are not bound to scientific accuracy. This creates what Dahlstrom and Scheufele (75) call a paradox of science storytelling—narratives can simultaneously engage audiences with science while also encouraging a narrative way of thinking that equates scientific knowledge with any other plausible narrative. Some might argue this engagement is necessary to remain relevant in a postfact society. However, journalism is similar to science in that it is a societal institution evaluated by alignment with external truth, and it has been criticized for focusing too much on the personalization and dramatization of issues instead of the bigger institutional and systemic realities (76). Science could face similar criticisms if it leans too heavily upon narrative persuasion in its public communication. Yet, science can look beyond using narrative to change attitudes about specific scientific findings to also use it to change attitudes about the process and truth value of science itself. This idea aligns with the value within science education on teaching the nature of science—what science is and how science works—and the promise of using narrative to do so (77). Future research should transfer the ideas about using narrative to teach the nature of science from the classroom to the larger media environment in an attempt to escape this paradox.

Active Audiences. The literature reviewed here has approached narrative from a media-centric view—conceptualizing narrative as a message that can impact an audience. However, audiences are not passive and make constant choices about what messages to attend to, how long to stay with each message, and how to interpret the content. These choices may collectively play a larger role in how narrative intersects with scientific misinformation within the larger information environment. How do science narratives work within this less controlled but more realistic environment of active audiences making choices within an ocean of possible contradictory messages and formats? Why do different audiences choose to read or watch certain science narratives? What gratifications are sought, and when are they met? How do audiences make sense of science narratives that contradict each other? Also, when do audiences take away different meaning from the same narrative? This audience-centric view applies a uses and gratifications framework to scientific narratives. While there is promising research examining some of these questions (38, 61, 78–80), this audience-centric view it is much less prominent in the literature, and future research could make important strides.

Complete the Feedback Loop. The literature reviewed here has also usually conceptualized the audience as the other who needs to be enlightened about science. However, scientists are also audiences, and we also process information through narrative thinking. Nagy et al. (81) interviewed scientists to discuss how negative myths about science have shaped their views of science, and the authors suggest that myths about science provide a way for scientists to understand popular concerns about their work and adjust future narratives accordingly. Future work should close this feedback loop and explore how scientific narratives, whether espousing misinformation or not, cycle back to influence the scientists themselves and what opportunities this feedback may afford.

Awe and Wonder. This review structured its discussion around the two most common goals that selected scientists reported for engaging with science communication: informing audiences through knowledge and defending science through persuasion (25). Yet, the third most common goal remains vastly understudied as a meaningful outcome variable within most of science communication and narrative literature: exciting audiences about science. The related emotions of awe and wonder have a long history in philosophy but were generally ignored in cognitive science and psychology because negative emotions were thought to be more powerful. However, these emotions have recently garnered more attention within psychology, and research suggests they can lead to powerful and long-lasting effects (82, 83). Science is well situated to serve as a context for awe and wonder because it already redefines what we know about the world through novel and often surprising ideas. Likewise, developing an appreciation for the beauty and wonder of science is already discussed as a goal within science education (39). Narrative as a communication format also seems well suited for this task because it is a simulation of human experience, with all of the complexities, contradictions, and wonder contained within. Yet, very little work has explored how narrative can excite audiences about science through awe and wonder and what the resultant outcomes would be with regard to scientific misinformation. Future research should explore these exciting possibilities.

Conclusion

What is the relationship between narrative and scientific misinformation? The literature synthesized in this review suggests a few major takeaways.

- Narrative is an inherently persuasive and subjective message format that portrays a bounded series of events through the experience of specific characters.
- Science and narrative differ in how they evaluate truth. Scientific truth is evaluated on alignment with external reality, while narrative truth is evaluated on the lifelikeness of its internal connections.
- Narrative can be both a cause of scientific misinformation and a remedy depending on how a narrator incorporates science into a particular narrative message.
- Audiences find it difficult to distinguish facts from falsehoods within narrative messages and often passively accept inaccurate knowledge.
- When contrasted with scientific information, narratives often have a disproportionate influence on attitudes and behaviors.
- Narratives may be well suited to improve scientific knowledge where making broader connections is desired.

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- Audiences often unknowingly change their attitudes and behavioral intentions to align with the perspective portrayed in narratives.

While the disparity between science and narrative can promote the acceptance of scientific misinformation, it also provides science with an opportunity to counter misinformation by making connections between accurate science knowledge and human experience. In the end, only scientists can know science through science. Everyone else must learn about science through other means. Narrative can turn it into a pretty good story.

Dr. Leandro told me to put the book down—she would show me how it works. She waved her card and we walked through the yellow doors marked "restricted access" into the greenhouse. I was greeted by hundreds of five-foot plants lined up in rows, each individually potted and tagged with a bar code. Hidden among the leaves were workers wearing safety glasses, watering a plant here, scanning a bar code there. This is where Dr. Leandro conducts her research. I had no idea how much effort went into answering such a seemingly simple question. I knew right away this work was too intimidating for me, but I now have such a greater appreciation for how science works. Dr. Leandro asked if I wanted to see where the robots use lasers to sort the seedlings. How can you say no to that?

Note Added in Proof. A longer version of this paper was posted on the SSRN preprint server (84).

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